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Runoff and Sediment Yield From Two Semiarid Sites in New Mexico's Rio Puerco Watershed[1]

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Precipitation, runoff, and sediment yield were measured from seven runoff plots at two different sites, in a calibration phase. Site 1 plots (fine sandy loam surface) were measured for 6 years (17 runoff events), and site 2 plots (clay loam surface) were measured for 3 years (12 events). Both runoff and sediment yield were significantly higher for the fine-textured site 2. Site 2 produced more sediment yield for a given runoff volume than site 1, indicating a higher erosion potential. Correlations between individual plots at each site for runoff and sediment yield were all significant. A single plot at each site was selected (based on highest r values) as a control plot for future treatment testing, and the number of future events necessary to detect a 25% and 50% change due to treatment was determined.

Keywords: Soil texture, precipitation, paired runoff plots, control plot selection

Introduction

The Rio Puerco drainage has the highest sediment load of any stream in the Upper Rio Grande Basin, and ranks among the highest in the nation (Dortignac 1956). During spring runoff and after summer storms, streamflow carries a high concentration of sediment. Although the Rio Puerco contributes less than 8% of the annual water yield in the Rio Grande above Elephant Butte Dam, it contributes about 45% of the annual sediment load (Dortignac 1956). The main channel of the Rio Puerco and most of its tributaries have formed vertical-walled gullies throughout the drainage system (Hickey and Dortignac 1964). The main channel is incised in alluvial material (up to 20 m deep) over most of its length. Tributaries are actively headcutting, some having nearly reached the upper ends of their alluvial flood plains. The relatively recent (past 100 years) high rate of gully erosion is associated with major changes in natural vegetation on the surrounding watersheds (Dortignac and Hickey 1963). Both total plant cover and density of productive perennial grasses have been substantially reduced. These changes coincided with a period (1880–1920) when an exceptionally high number of livestock were stocked, which peaked around 1900. Thus, it is fair to conclude that this excessive animal use had a major effect on the present degraded condition of the Rio Puerco watershed.

The objectives of this study included the following: (1) to assess runoff and erosion relationships on representative sites and (2) to establish what control calibration periods would be required to test watershed treatments such as livestock trampling.

Study Area

Seven runoff plots were located on the Rock House allotment 9.4 miles west of the Zia Indian Pueblo in northern New Mexico. Four replicated plots are located

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on Querencia soil series (site 1) and three on the San Mateo series (site 2). Site 1 has a fairly thick (15 cm) fine sandy loam topsoil overlying a sandy clay subsoil. Vegetation is a degraded perennial grass stand with total plant cover generally less than 15%. More than 50% of the cover is broom snakeweed (*Gutierrezia sarothrae*). The site is on a smooth, unbroken, north-facing slope (about 5%). Site 2 has been eroded such that most of the topsoil is missing, leaving weathered shale alluvium (clay loam) on the surface. Vegetation is similar in composition to site 1 but total cover is less than 10%. Site 2 is about 300 m north of site 1, on a smooth, unbroken, west-facing slope (about 3%). A vertical-walled gully (3 m deep), about 200 m to the west, is head-cutting up the slope toward the site. Mean annual precipitation (1983–87) was 31.6 cm, with summer convective storms contributing 55% of the total.

The test plots have been maintained in a control period (no treatment) from 1982 through 1987. Some light grazing (<25% utilization of available forage) occurred from 1982 through 1984 but no grazing occurred after 1984.

Instrumentation and Measurements

Water runoff from site 1 was measured using rectangular bordered plots (3.9 m across slope by 9.4 m along slope) and 2000-liter galvanized steel tanks (Garcia et al. 1963). This plot design used a trough along the downslope end to collect water and pipe it to the tanks. The installation at site 2 was modified to reduce time and cost of installation and reduce risk of water loss from pipes and tanks. Conventional 1200-liter rectangular stock tanks were buried in the ground at the base of the plots, with the upper edges of the tanks at the soil surface. Water runoff from the bordered plots (2.4 m by 7.6 m) entered directly into the tanks. To prevent soil-piping, surface channels were constructed to direct outside surface water away from the tanks. The tanks were fitted with insulated lids attached with hinges. Lids were constructed of Styrofoam board (1.9 cm) bonded between galvanized roofing and plywood (0.64 cm). Gravity drains with cutoff valves were fitted to the tanks to facilitate cleaning.

Daily rainfall and runoff were automatically recorded on an A-to-D millivolt recorder using magnetic tape storage. Capacitance type water-level sensors were used as rainfall and runoff inputs to the recorder. The sensors were installed in cylindrical plastic water containers (10.2 cm dia. by 60 cm deep). The rainfall water container and sensor were installed vertically in a recording gauge housing so that rain water entering the gauge was directed into the water container. The runoff water container and sensor were installed vertically in a small (400-liter) tank inside one of the large tanks (site 1, tank 2). Holes were cut in the bottom of the container so that water from the tank would fill the container.

The water-level sensors consisted of a small, inexpensive, IC-based RF oscillator, coupled to a 60-cm-long transmitter rod. The rod (6 mm brass) was sealed inside a tight-fitting Teflon tube (10 mm) and this assembly was supported at each end inside a 19-mm stainless steel tube. Four holes (3 mm) were drilled through the wall of the stainless tube just above the bottom support to allow water to enter the air space between the Teflon and the stainless surfaces. Air escaped through a hole drilled at the top of the tube. The stainless tube was wired to the oscillator common so that the rod and tube assembly acted as a tuning capacitor. As water rose in the space between the rod and tube, the electric capacitance increased and the oscillator frequency dropped. Ordinary coaxial antenna cable was used to conduct the RF signal to the instrument shelter. A frequency-to-voltage interface with gain, minimum and maximum controls was used for signal conditioning ahead of the recorder.

Suspended sediment yield (Kg ha^{-1}) was obtained after each storm by manually stirring the contents and removing a 1.0-liter representative sample of the runoff from all tanks. The depth of water in each tank (cm) was also recorded as a backup to the automatic system. Sediment concentration was determined by drying the sample and weighing it.

Measurements were taken for each storm event during the control period (1982–1987) except when two storms occurred close together and sediment samples were missed on the first storm (plots were checked weekly). Individual storm date, rainfall, and runoff were available from the automatic logger.

A paired *t*-test was used to determine if site 1 and site 2 mean runoff and sediment yields by storm were significantly different. Site 1 data through 1984 were not included in the analyses as site 2 data for the period were not available. An extension of the Kovner and Evans (1954) technique was used to determine how many future events would be needed to detect a given change resulting from future treatments. Type I error (alpha) and type II error (beta) were set at 0.05.

Results and Discussion

Sites 1 and 2 were significantly different ($p = 0.01$) when grand means for both runoff and sediment yield were compared (table 1). Runoff expressed as a percentage of average rainfall was 8% on site 1, while at site 2 it was much more (32%). Soil texture is believed to be the major factor causing these differences. Slope is actually less on site 2 than on site 1, which should eliminate it as a factor. Total vegetative cover, however, is about one-third lower on site 2 and bare areas tend to be larger, allowing water to flow more directly across the plots. Not only does site 2 produce more runoff but also proportionally more sediment. For each 1 cm of runoff, site 2 produces 2.7 times more sediment; and therefore, the finer textured soil is likely more erosive. Individual plot values for runoff and sediment are shown for further reference in appendixes 1 and 2.

Correlations between all plot combinations (using all storms) indicated that plot 3 at site 1 and plot 1 at site 2 had the consistantly highest correlation values with other plots. Therefore, these plots were selected as controls for future treatments. All correlations with these plots were significant ($p = 0.01$) (table 2).

Table 1.—Precipitation, mean runoff, and mean sediment yield on site 1 (Querencia fine sandy loam, n = 4) and site 2 (San Mateo clay loam, n = 3).

Date[1]	Precip.	Runoff		Sediment	
		Site 1	Site 2	Site 1	Site 2
	----------cm----------			----Kg ha^{-1}----	
9/13 + 9/15/85	1.60	0.23	0.73	54	639
9/18 + 9/20/85	4.70	0.69	2.02	133	764
10/10 + 10/16/85	4.20	0.15	1.24	13	155
6/18/86	1.20	0.00	0.33	0	270
6/26 + 6/27/86	2.70	0.00	0.16	0	51
7/7/86	2.00	0.38	1.20	61	673
8/8 + 8/10/86	1.20	0.37	0.72	30	153
9/7/86	1.20	0.24	0.33	37	127
9/13/86	1.20	0.30	0.83	43	443
10/10 + 10/14/86	3.50	0.25	2.17	2	208
8/24/87	2.70	0.00	0.50	0	275
11/1/87	1.60	0.11	0.25	22	222
Grand mean[2]	2.71	0.23a	0.87b	33a	332b

[1]*The + indicates that events were combined.*
[2]*Grand means (for runoff or sediment) with different letters are significantly different (p = 0.01).*

Table 2.—Correlation[1] between plots for runoff and sediment at sites 1 and 2.

Plot comparisons[2]	Runoff		Sediment	
	Site 1	Site 2	Site 1	Site 2
1 vs 3	0.97	—	0.95	—
2 vs 3	0.96	—	0.99	—
4 vs 3	0.98	—	0.98	—
2 vs 1	—	0.97	—	0.95
3 vs 1	—	0.92	—	0.88

[1]*All r values were significant (p = 0.01).*
[2]*Plot 3 at site 1 and plot 1 at site 2 were selected as control plots for future treatment testing.*

To estimate the length of a future study, the number of events required to detect a given difference between the control and a treated plot was calculated (table 3). Using an estimate of three runoff-producing storms per year, approximately 12 years would be needed to detect a 25% difference in water runoff and sediment yield. Approximately 3 years would be needed for a 50% difference. Future treatment plans include one control plot (no trampling) and 30%, 60%, and 90% hoof-print coverage on individual plots.

Table 3.—Number of future storm events required to detect a 25% and 50% difference between the control and treated plots.[1]

Site	Treated plot	Runoff difference		Sediment difference	
		25%	50%	25%	50%
1	1	23	4	—	17
1	2	34	5	19	3
1	4	63	6	—	10
2	2	23	4	38	4
2	3	—[2]	24	—	—

[1]*Type I and II error = 0.05.*
[2]*A solution not found.*

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Appendix 1.—Precipitation, runoff, and sediment on four plots installed in 1982 on Querensia fine sandy loam (site 1).

Date[1]	Storm precip.	Plot runoff				Plot sediment			
		1	2	3	4	1	2	3	4
	cm					*Kg ha^{-1}*			
8/24 + 8/26/82	4.7	1.20	0.96	0.95	0.84	305	413	368	249
9/16/82	1.3	0.28	0.19	0.23	0.26	70	83	88	78
7/26 + 8/2/83	6.0	1.20	0.96	0.96	0.72	415	380	330	258
8/3 + 8/7/84	3.9	1.44	0.96	1.02	0.91	441	337	296	296
10/3/84	2.4	0.48	0.36	0.36	0.30	124	57	61	57
9/13 + 9/15/85	1.6	0.35	0.23	0.22	0.10	79	61	51	23
9/18 + 9/20/85	4.7	0.88	0.82	0.60	0.47	139	200	114	80
10/10 + 10/16/85	4.2	0.37	0.22	0.00	0.00	20	31	0	0
6/18/86	1.2	0.00	0.00	0.00	0.00	0	0	0	0
6/26 + 6/27/86	2.7	0.00	0.00	0.00	0.00	0	0	0	0
7/7/86	2.0	0.55	0.52	0.32	0.13	82	77	59	26
8/8 + 8/10/86	1.2	0.53	0.45	0.31	0.19	44	42	19	13
9/7/86	1.2	0.38	0.30	0.24	0.04	61	40	40	6
9/13/86	1.2	0.46	0.32	0.24	0.19	54	36	40	42
10/10 + 10/14/86	3.5	0.00	0.10	0.00	0.00	0	8	0	0
8/24/87	2.7	0.00	0.00	0.00	0.00	0	0	0	0
11/1/87	1.6	0.24	0.19	0.00	0.00	48	40	0	0

[1]*The + indicates that events were combined.*

Appendix 2.—Precipitation, runoff, and sediment on three plots installed in 1985 on San Mateo clay loam (site 2).

Date[1]	Storm precip.	Plot runoff			Plot sediment		
		1	2	3	1	2	3
	cm				*Kg ha^{-1}*		
9/13 + 9/15/85	1.6	0.88	0.76	0.55	762	754	402
9/18 + 9/20/85	4.7	1.97	2.12	1.96	838	788	667
10/10 + 10/16/85	4.2	1.48	1.55	0.69	155	213	96
6/18/86	1.2	0.40	0.41	0.18	365	292	152
6/26 + 6/27/86	2.7	0.27	0.21	0.00	89	65	0
7/7/86	2.0	1.26	1.30	1.03	867	781	372
8/8 + 8/10/86	1.2	0.84	0.77	0.55	216	213	29
9/7/86	1.2	0.73	0.26	0.00	248	133	0
9/13/86	1.2	0.95	0.81	0.73	496	421	411
10/10 + 10/14/86	3.5	2.55	2.24	1.73	231	212	181
8/24/87	2.7	0.58	0.49	0.44	366	226	233
11/1/87	1.6	0.32	0.43	0.00	252	414	0

[1]*The + indicates that events were combined.*